Geologic Map of the Charleston Quadrangle, Coos County, Oregon

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EXPLANATION OF MAP UNITS

QUATERNARY DEPOSITS

Qaf **Artificial fill (recent)**—Sand, silt, and rock fill in the Charleston harbor area

Qs **Quaternary sand deposits (Holocene)**—Unconsolidated beach and dune sand deposited along ocean and bay shores. Seasonal, narrow, and pocket beaches not shown

Qal **Quaternary alluvium and estuarine sediments (Holocene)**—Sand, silt, peat, and clay deposited in sloughs and valley bottoms. Generally restricted to elevations below 6 to 9 m above sea level. Alluvium 40 m thick was logged in a borehole in the center of Joe Ney Slough beneath the current bridge

Qe **Quaternary estuarine deposits (Pleistocene)**—Poorly consolidated clay, silt, peaty mud, and pebbly mud banked into modern river valleys. Possibly associated with the Whiskey Run or Pioneer marine terraces

UNCONFORMITY

Quaternary marine terraces (Pleistocene)—Weakly consolidated sand, friable sandstone, and minor pebble conglomerate deposited in littoral conditions during successive marine transgressions associated with Pleistocene interglacial periods. Marine terrace deposits overlie older Tertiary rocks with angular unconformity along a wave-cut platform. Marine terrace sands are typically feldspathic, medium to coarse grained, and moderately well rounded and sorted to well rounded and sorted. Mica is locally common. The pebble conglomerate clasts are typically exotic lithologies, including metamorphic rocks, quartz, and basalt. Local bedrock lithologies are rare in the conglomerate. Locally, terrace deposits include sand dunes that may or may not be associated with a wave-cut platform. Mapped originally as "Elk River Beds" by Diller (1902) and Allen and Baldwin (1944), five distinct terraces were mapped by Griggs (1945) and have been correlated west of South Slough on the basis of relative elevation and soil development (McInelly and Kelsey, 1990). Bockheim and others (1992) describe a soil chronosequence for the marine terraces west of South Slough. Terraces east of South Slough are speculatively correlated by relative elevation, extent, and limited soils information. For any given terrace, the current height above sea level is highly variable because of late Quaternary deformation

Qwr **Whiskey Run marine terrace (Pleistocene)**—Lowest terrace; present around Coos Head, southeast of Bastendorff Beach, and between Yoakam Point and Sunset Bay. Terrace cover sediments are typically thin (3–5 m) in the map area. Solitary coral within the cover sediments has been dated south of the map area at 83±5 ka (thousand years) B.P. (before the present) (Muhs and others, 1990)

Qpi **Pioneer marine terrace (Pleistocene)**—Well-developed terrace at Coos Head. Thickness in the map area is 3–8 m. Age estimated as 105 ka B.P. (Muhs and others, 1990; McInelly and Kelsey, 1990)

Qsd **Seven Devils marine terrace (Pleistocene)**—Extensively developed terrace on both sides of South Slough. West of South Slough, the average thickness of terrace cover sediments is 3–18 m. Terrace cover sediments east of South Slough appear thicker, up to at least 28 m at Valino Island. Age speculatively estimated as 125 ka B.P. (McInelly and Kelsey, 1990)

Qmc **Metcalf marine terrace (Pleistocene)**—Extensively developed and preserved terrace capping ridges west and east of South Slough. West of South Slough, the terrace cover sediments average 3–16 m thick. East of South Slough, terrace cover sediments are up to 42 m thick in sec. 12, T. 27 S., R. 14 W., and 48 m thick in a borehole at upper Pony Creek Reservoir. Age speculatively estimated as 200 ka B.P. (McInelly and Kelsey, 1990)

Qap **Arago Peak marine terrace (Pleistocene)**—Scattered remnants capping ridges west of South Slough. Thickness 13–17 m. No age estimated

ANGULAR UNCONFORMITY

TERTIARY SEDIMENTARY ROCKS

Tme **Empire Formation (upper Miocene; Graysian)**—Massive, micaceous, bioturbated, fossiliferous, fine- to medium-grained quartzofeldspathic wacke (Armentrout, 1967), with minor siltstone, conglomerate, and water-laid tuff. Concretions are common. Conglomerate consists of pebbles of basalt, quartzite, and chert; pebbles to boulders of Empire Formation sandstone; and invertebrate fossils. Gray where fresh; tan where weathered. Armentrout (1967) reports a thickness of at least 500 m; greater thickness is possible in the axis of the South Slough syncline. Extensive exposures in sea cliffs around Coos Head and at low tide along the Coos Bay shore north of Charleston, in Joe Ney Slough, and along much of the South Slough shoreline. The low-tide exposures are generally not depicted on the map in South Slough. One distinctive bed of highly fossiliferous (molluscs) intraformational conglomerate at Fossil Point was called the Coos conglomerate by Dall (1898, 1909). Age of the

Empire Formation has been determined as early Pleistocene to late Pliocene by Dall (1909), middle to late early Pliocene by Weaver and others (1944), middle to early Pliocene by Armentrout (1967), late Miocene (Wishkahan) by Addicott (1976), and, most recently, late Miocene (Graysian) by Armentrout and others (1983)

Not shown **"Miocene beds" (Tarheel formation of Armentrout [1967]) (middle to lower Miocene; Newportian)**—Fossiliferous, concretionary, lithic wacke (Armentrout, 1967). Originally identified from dredge spoils described by Moore (1963). Armentrout (1967) later discovered limited exposure in the intertidal zone along the Coos Bay shore in sec. 30, T. 25 S., R. 13 W., and described the molluscan fauna. At least 8 m of section were exposed at this site at the time of Armentrout's study. No exposures of this unit were visible during the field work for this map. There may be a slight angular discordance with the overlying Empire Formation (Armentrout, 1967), although the massive nature of the Empire Formation limits the precision of bedding-attitude measurements. Because of the extremely limited exposure and total lack of subsurface information about this unit, it is depicted as part of the Empire Formation on the map and in the cross sections. Armentrout (1967) and Armentrout and others (1983) informally named these rocks the "Tarheel formation"

ANGULAR UNCONFORMITY

Tetp **Tunnel Point Sandstone (upper Eocene; Galvinian)**—Fine tuffaceous sandstone with fine sandy siltstone and minor conglomerate. Schenck (1928) reports angular to subangular basaltic and andesitic glass make up 90 percent of the rock with subordinate feldspar, muscovite, and biotite. Light gray to tan in sea cliff and road cut exposures. Thickness of at least 245 m measured by Allen and Baldwin (1944). Conformably overlies the Bastendorff Shale and is overlain by the "Miocene beds" or Empire Formation with a major angular unconformity (approximately 58° difference in dip at Coos Head). Exposure limited to sea cliffs (now abandoned due to accretion of Bastendorff Beach following the construction of jetties at the mouth of Coos Bay) and road cuts in the SE¼ sec. 3, T. 26 S., R. 14 W. Fossiliferous with a Galvinian molluscan fauna (Armentrout, 1975, 1980; Armentrout and others, 1983). Age originally determined by Dall (1898) as middle Oligocene

Teb **Bastendorff Shale (upper Eocene; Narizian, Refugian)**—Finely laminated siltstone with mudstone, minor sandstone, tuffaceous siltstone, and water-laid tuff. Gray where fresh; yellow or orange brown where weathered. Thickness measured by Allen and Baldwin (1944) as 885 m. Actual thickness may be somewhat greater if there is significant stratigraphic separation along the Miner Creek fault. Conformably overlies the upper Coaledo Formation and is conformably overlain by the Tunnel Point Sandstone. Age was originally determined to be Oligocene (Dall, 1909), lower Oligocene (Cushman and Schenck, 1928), upper Eocene-lower Oligocene (Tipton, 1975), and upper Eocene (Rooth, 1974; Warren and Newell, 1981; Armentrout and others, 1983). Foraminiferal faunas studied by Rooth (1974) and Tipton (1975) indicate a bathyal to abyssal environment for the lower Bastendorff, shallowing upward to bathyal to neritic in the upper Bastendorff

Coaledo Formation (upper to middle Eocene; Narizian)—Sandstone, siltstone, and mudstone with minor subbituminous coal and conglomerate. Originally defined by Diller (1899) and divided by Turner (1938) into upper and lower coaly sandstone members and a middle siltstone and mudstone member (Baldwin and others, 1973). Dott (1966) studied the composition of the sandstones and reported that they were "texturally submature to immature: feldspathic, micaceous, and carbonaceous lithic (volcanic) arenites and lithic (volcanic) wackes." Dott (1966) and Ryberg (1978) interpreted the Coaledo as a prograding wave-dominated deltaic complex deposited on an open coast, with a sediment source to the southeast. Allen and Baldwin (1944) mapped all three members west of South Slough but did not differentiate them east of South Slough in the map area. Baldwin and others (1973) mapped all three members east of South Slough. The three members are easily mapped in the excellent coastal exposures between Sunset Bay and Bastendorff Beach and can be clearly traced on the basis of topography on the west side of South Slough. Mapping east of South Slough is difficult. Exposures are rare, and the topographic expression of the units is far less clear. Stratigraphic interpretations of three oil wells (Robertson, 1982) were used to anchor the mapping along the eastern margin of the map. Two of the wells, Northwest Exploration Westport 1 (sec. 16, T. 26 S., R. 13 W.) and Warren Coos County 1–7 (sec. 7, T. 27 S., R. 13 E.) are located just off the map. The third, Phillips Petroleum Dobbyns 1, is located in sec. 28, T. 26 S., R. 13 W.

Tecu **Upper Member of the Coaledo Formation (upper to middle Eocene; Narizian)**—Fine to coarse lithic feldspathic micaceous sandstone with siltstone, mudstone, coal, and minor conglomerate. Ryberg (1978) and Chan and Dott (1986) report six to eight upward-coarsening successions from prodelta-shelf facies through delta-front facies, culminating in either delta-distributary facies or delta-margin facies. Common sedimentary structures include planar bedding; hummocky cross-stratification; trough, ripple, low-angle, and planar-tabular cross-stratification; contorted cross-beds; liquefaction dikes; intraformational mudstone clasts; burrows; flaser bedding; concretions; flame structures; coquina lags; slumped bedding; and scours. Allen and Baldwin (1944) measured a thickness of 400 m between Lighthouse Beach and Bastendorff Beach. Rooth (1974) reports Narizian foraminifera

Tecm **Middle Member of the Coaledo Formation (upper to middle Eocene; Narizian)**—Mudstone, siltstone, and some sandstone. Allen and Baldwin (1944) measured a thickness of 890 m at Lighthouse Beach. Sedimentary structures are less abundant than in the Upper and Lower Members of the Coaledo Formation and include plane laminated beds, hummocky cross-stratification, and complete to partial Bouma sequences in sand beds. Bioturbation is common (Chan and Dott, 1986). Chan and Dott (1986) interpreted the Middle Member of the Coaledo Formation to be largely prodelta-shelf facies with some shelf to slope deposits. Rooth (1974) reports Narizian upper bathyal to lower neritic foraminiferal assemblages

Tecl **Lower Member of the Coaledo Formation (upper to middle Eocene; Narizian)**—Fine to coarse lithic feldspathic sandstone with siltstone, mudstone, coal, and minor conglomerate. Chan and Dott (1986) and Ryberg (1978) report ten upward-coarsening successions from prodelta-shelf facies through delta-front facies, culminating in either delta-distributary facies or delta-margin facies. Common sedimentary structures include planar bedding; hummocky stratification; trough, ripple, low-angle, and planar cross-stratification; contorted cross-beds; clastic dikes; intraformational mudstone clasts; burrows; flaser bedding; concretions; flame structures; coquina lags; slumped bedding; and scour-and-fill structures. Allen and Baldwin (1944) measured a thickness of 540 m west of Sunset Bay. Rooth (1974) reports Narizian foraminifera

Tes **Beds at Sacchi Beach (middle Eocene; Narizian)**—Micaceous siltstone and mudstone. Outcrops in map area restricted to poor road-cut exposures of brown to reddish-brown massive mudstone. Baldwin and others (1973) report a thickness of at least 550 m at Sacchi Beach, located just west of the southwest corner of the quadrangle. Allen and Baldwin (1944) mapped these rocks as Umpqua Formation, while Baldwin and others (1973) mapped them as the Elkton Siltstone Member of the Tyee Formation and assigned them a middle Eocene Ulatisian age on the basis of foraminifera examined by Stewart (1957). P.D. Snavely, Jr., (U.S. Geological Survey, personal communication, 1995) reports CP14a stage coccoliths from the road cut exposures, indicating a middle to late Eocene age (Bukry and Snavely, 1988), significantly younger than the CP12a age of the Elkton Formation (Ryu and others, 1992)

INTRODUCTION

This mapping project was originally proposed as part of U.S. Geological Survey (USGS) Cooperative Agreement 14–08–0001–AO512 under the National Earthquake Hazard Reduction Program (NEHRP). Publication of the map was funded by USGS NEHRP Award 1434–93–G–2324. McInelly and Kelsey's contributions were supported in part by USGS NEHRP Award 14–08–0001–G1387. The purpose of the map is to provide a detailed geologic and structural framework to aid interpretations of evidence for local Quaternary deformation and prehistoric subduction earthquakes that was recovered from Holocene marsh deposits in South Slough and Coos Bay (Peterson and Darienzo, 1989; Nelson and Personius, 1991; Briggs, 1994). Specifically, the goal was to map bedrock structure and Quaternary deformation of marine terraces, and no original stratigraphic or paleontologic investigation of bedrock units was done. The ages and characteristics of the bedrock units on this map are drawn largely from the literature. Geologic maps including the Charleston quadrangle have been published several times in the past, starting with Diller (1901), Allen and Baldwin (1944), Baldwin and others (1973), Beaulieu and Hughes (1975), Ryberg (1978), and Newton and others (1980). Of these, Allen and Baldwin (1944) did the most mapping in the Charleston quadrangle, working at a scale of 1:125,000.

McInelly and Kelsey are responsible for mapping and correlating the marine terraces west of South Slough. Madin is responsible for marine terrace mapping and correlation east of South Slough, all bedrock structure mapping, and fault trenching.

STRUCTURE

The complex structure of the Charleston quadrangle results from roughly east-west compression that began sometime in the Oligocene or Miocene and continues today. This deformation has produced many north-trending folds, north-trending reverse and thrust faults, and west-northwest-trending steep reverse(?) faults. The style of deformation in general is similar to that depicted for the active Cascadia fold and thrust belt by Goldfinger and others (1992).

Folds

The main structure in the quadrangle is the South Slough syncline, which plunges north through the center of the quadrangle. The South Slough syncline is markedly asymmetric. The west limb consists of (1) relatively uniformly east-dipping Coaledo and Bastendorff beds, which strongly control topography and are cut only by a few minor cross faults (Sunset Bay faults); (2) bedding plane reverse faults (Miner Creek and Hayward Creek faults and unnamed faults in sec. 34, T. 26 S., R. 14 W., and sec. 3, T. 27 S., R. 14 W.); and (3) the Charleston fault, a major north-trending reverse or thrust fault near the syncline axis. The east limb has numerous minor folds and is cut by north-trending, west-dipping reverse faults or thrusts (e.g., Winchester fault), and several west-north-west-trending high-angle faults (e.g., Joe Ney fault). The asymmetry is also pronounced in terms of stratigraphy, with a significant exposure of Bastendorff Shale and Tunnel Point Sandstone on the west limb and no Tunnel Point Sandstone and little Bastendorff Shale on the east limb south of the Joe Ney fault.

The other major feature of the South Slough syncline is a major east-trending kink across the southern part of the syncline. On the west limb, the strike of the beds changes from 0–20° NW. to 60–80° NW. in secs. 27, 28, 33, and 34, T. 26 S., R. 14 W., and back to 20–30° NW. in secs. 2 and 3, T. 27 S., R. 14 W. A similar kink occurs on the east limb in secs. 29, 30, 31, and 32, T. 26 S., R. 13 W. This kink does not appear to involve a fault at the surface, particularly in the west limb, where numerous continuous strike ridges are visible in aerial photographs. The kink may be due to differential response to folding of deeper units. There is a difference in elevation of over 945 m (down to the south) to the top of Siletz River Volcanics encountered in oil wells between the Northwest Exploration Westport 1 and Phillips Petroleum Dobbyns 1 to the north and the Warren Coos County 7–1 to the south (Newton and others, 1980; Black, 1992).

Numerous minor anticlines and synclines occur along the east limb of the South Slough syncline. Some appear to be associated with west-dipping reverse or thrust faults. Strike and dip data are sparse in much of the area, so it is difficult to trace individual fold axes for any significant distance. A particularly complex area of folding occurs in secs. 31 and 32, T. 26 S., R. 13 W., and secs. 5 and 6, T. 27 S., R. 13 W. Attitudes are scarce and vary wildly. The folded anticline axis depicted on the map is based in part on the appearance of strike ridges in the topography.

Quaternary deformation of the South Slough syncline is demonstrated by back-tilting of marine terraces (Griggs, 1945; Adams, 1984; McInelly and Kelsey, 1990), landward dips of the Metcalf terrace (unit Qmc) as high as 13° (sec. 26, T. 26 S., R. 14 W.), faulting of marine terraces by flexural slip bedding plane faults (Adams, 1984; McInelly and Kelsey, 1990), and systematic differences in elevation between terraces across the strike of the west limb of the fold (McInelly and Kelsey, 1990). The smaller scale folds on the east limb of the South Slough syncline have probably also been active throughout the Quaternary.

Faults

Most faults in the Charleston quadrangle can be assigned to one of three classes: (1) generally north-trending reverse or thrust faults on the east limb of the South Slough syncline, (2) bedding-plane reverse faults on the west limb of the South Slough syncline, and (3) west-northwest-trending, north-dipping(?) reverse faults. Faults were identified in this study by direct observation in natural and manmade exposures; observation of scarps or lineaments in Quaternary marine terrace deposits; inference from contact relations of marine terrace sediments; and observation of offsets, scarps, and lineaments on aerial photographs taken at roughly 10- to 15-year intervals from 1939 to 1991.

North-trending reverse and thrust faults

North-trending reverse and thrust faults are present only along the axis and the east limb of the South Slough syncline. The Charleston fault, first described by McInelly and Kelsey (1990), is well exposed in a small cove west of Coos Head, where the Pioneer marine terrace (unit Qpi) is offset 19 m down to the east. Immediately adjacent to the fault the terrace warps down dramatically. On the downthrown side, the marine terrace cover sediments are cut by liquefaction sand dikes and have collapsed along a series of meter-scale secondary faults into a small graben along the fault. Abundant springs occur along the fault where the contact between the impermeable Empire Formation and permeable Pioneer terrace sediments intersects the ground surface along the fault. On the basis of mesoscale faulting in the Empire Formation bedrock adjacent to the main fault, McInelly and Kelsey (1990) concluded that the Charleston fault dips steeply. An alternative thrust or reverse fault model is based on the warping of the terrace on the upthrown side of the fault, similar to warping of the terrace observed in a trench across the Winchester fault (a thrust described below). The Charleston fault is clearly late Quaternary in age, as evidenced by the 19-m offset of the Pioneer terrace. McInelly and Kelsey (1990) argue that the fault may also deform the Whiskey Run terrace (unit Qwr), indicating movement within the last 80,000 years.

A minor (antithetic?) splay of the Charleston fault occurs immediately west of Charleston, where the contact between slightly weathered, plane-bedded Pioneer terrace strata and an overlying blocky massive B soil horizon is cut by a fault trending N. 10° W. and dipping 75° W. The sense of offset is east side up, and bedding is tilted to the west on the downthrown side.

The Winchester fault is a northeast-trending, east-dipping thrust fault that can be traced for at least 5 km just east of Winchester Creek. The fault was first identified in road cuts in Cox Canyon, where a generally flat Metcalf-age wave-cut terrace is interrupted by an east-facing bedrock (unit Tecu) high. South of Cox Canyon, in the northwest corner of sec. 1, T. 27 S., R. 14 W., an 8-m-high north-trending scarp is visible on recent clear-cuts. Three trenches up to 50 m long and 5 m deep were excavated across the fault in September 1993. The trenches revealed at least two major 20°-west-dipping thrusts that folded and overturned the Metcalf platform on the hanging wall and thrust upper Coaledo sandstone over slightly eastward-dipping Metcalf terrace sediments in the footwall. At least two colluvial wedges were cut by the fault, which suggests multiple late-Quaternary ruptures. All carbon from the colluvial wedges was radiocarbon dead (age 47,800 years). The only unit not cut by the faults is the modern forest soil, which is about 1 m thick. The Winchester fault can be traced north on aerial photographs across Cox Canyon and John B. Creek to Talbot Creek as a reversal of slope along ridge crests in Metcalf terraces. It is also exposed to the south in logging roads in the SE sec. 2, T. 27 S., R. 14 W. Total vertical offset of the Metcalf platform is 50 m (the thickness of the terrace cover sediments plus the scarp height). The actual slip is approximately 146 m, if the dip of the fault is constant at depth. This suggests a maximum slip rate of 0.73 mm/yr for the last 200 ka, assuming the age of the Metcalf terrace is about 200 ka (McInelly and Kelsey, 1990).

Three other late Quaternary thrusts are inferred adjacent to the Winchester fault. One to the west between the Winchester fault and Winchester Creek is suggested by a discontinuous north-trending berm visible on aerial photographs. The second parallels the Winchester fault about 0.5 km to the east and is defined by a north-trending ridge in the marine terrace sediments and anomalously high exposures of bedrock in the southeast corner of sec. 1, T. 27 S., R. 14 W. The third lies just west of Winchester Creek, south of Wasson Creek, and is suggested by an abrupt break in the relatively flat-lying Metcalf platform to the west and limited exposures of 20°-east-dipping platform and terrace sediments east of the fault.

The Barview fault was first identified by McInelly and Kelsey (1990) and named the Barview-Empire fault. It is exposed in sea cliffs along the west shore of Coos Bay, where it offsets the Seven Devils (or Whiskey Run [McInelly and Kelsey, 1990]) platform by about 1 m down to the north. Northwest-striking, moderately southwest-dipping mesoscale faults in the overlying terrace sediments suggest that the Barview fault is a thrust or shallow reverse fault. McInelly and Kelsey (1990) reported that tree stumps in the beach on the downthrown side might have been killed by coseismic submergence during an earthquake on the Barview fault. Radiocarbon dates of the stumps range from 220 years B.P. to modern, suggesting Holocene displacement. Several living and dead trees currently exist just above the tide zone adjacent to the buried stumps. This raises the possibility that the buried stumps were killed by normal wave erosion.

The Crown Point fault is a west-dipping thrust or reverse fault that extends along the east shore of South Slough between Day Creek and Joe Ney Slough. The fault is inferred on the basis of a sinuous, low scarp observed on aerial photographs and numerous minor faults observed in road cuts of Metcalf terrace sediments. The Crown Point fault is late Quaternary in age.

Several other north-trending reverse or thrust faults occur on the east limb of the South Slough syncline. One, in secs. 29 and 20, T. 26 S., R. 13 W., forms an east-facing scarp in Metcalf terrace deposits that is visible on aerial photographs in the NW¼ sec. 29 and the SW¼ sec. 20. Between Elliot Creek and Day Creek in secs. 13 and 24, T. 26 S., R. 14 W., another fault juxtaposes Empire Formation sandstone on the west and Metcalf terrace sand to the east. A third fault extends from Day Creek to Joe Ney Slough through secs. 7 and 18, T. 26 S., R. 13 W., where it juxtaposes sandstone of the Upper Member of the Coaledo Formation on the west and Metcalf terrace sediments on the east. A fourth fault extends through secs. 18, 17, 8, and 5, T. 26 S., R. 13 W., and juxtaposes bedrock and Metcalf terrace sediments at several locations. All of these faults are late Quaternary in age.

Bedding-plane reverse faults

East-dipping bedding-plane reverse faults are common on the western limb of the South Slough syncline. All cut marine terraces and are late Quaternary in age.

The Yoakam Point fault was first reported by Baldwin (1966) as the Mussel Reef fault. It is a bedding-plane reverse fault that occurs within a 1- to 2-m-thick coal bed in the Upper Member of the Coaledo Formation. The fault also offsets both the Whiskey Run terrace platform and the land surface by about 3–4 m and produces a scarp that can be followed for tens of meters. No buried colluvial wedges are visible in the sea cliff exposure across the scarp, suggesting a single late Quaternary faulting event.

The Bastendorff fault was identified by McInelly and Kelsey (1990) through observation of an offset of 4 m in the Whiskey Run platform immediately southeast of Bastendorff Beach.

The Miner Creek fault offsets the Metcalf terrace by 25 m (McInelly and Kelsey, 1990) and forms part of the contact between the Upper Member of the Coaledo Formation and Bastendorff Shale in Miner Creek.

The Hayward Creek fault offsets the Metcalf terrace by 6 m (McInelly and Kelsey, 1990).

The Coos Head fault juxtaposes the Empire Formation and Tunnel Point Sandstone and strongly warps bedding in the Tunnel Point Sandstone. In aerial photographs, a poorly defined scarp is evident where the fault crosses the Pioneer terrace.

Two unnamed bedding-plane reverse faults occur in sec. 34, T. 26 S., R. 14 W., and sec. 3, T. 27 S., R. 14 W. One runs east of Seven Devils Road and is clearly visible on aerial photographs as a west-facing scarp about 3 to 4 m high in Metcalf terrace sediments. The second is west of Seven Devils road and is visible in logging road cuts in the NE¼SW¼ sec. 34. The Metcalf platform is tilted 13° SW. and is offset at least 1 m.

West-northwest-trending faults

West-northwest-trending faults are common on the east limb of the South Slough syncline and rare on the west limb. In general, the dips are steep, and offsets are down to the north.

The largest of the west-northwest-trending faults is the Joe Ney fault. It juxtaposes the Upper and Middle Members of the Coaledo Formation in sec. 17, T. 26 S., R. 13 W., and Upper and Lower Members of the Coaledo Formation just east of the map area in sec. 16, T. 26 S., R. 13 W. Offset is several hundred meters down to the north. The fault cuts Metcalf terrace sediments in sec. 7, T. 26 S., R. 13 W., which indicates some late Quaternary movement.

Two other west-northwest-trending faults occur south of the Joe Ney fault. The northernmost one cuts Metcalf terrace sediments in sec. 17, T. 26 S., R. 13 W., and is down to the north. The southernmost one is also down to the north but does not appear to cut Quaternary units.

The only significant west-northwest faults on the west limb of the South Slough syncline are the Sunset Bay faults, a group of over a dozen faults spectacularly exposed in sea cliffs and the modern wave-cut platform from just south of Sunset Bay to Gregory Point. The sense of offset varies from fault to fault, with vertical displacements in the range of a few meters to tens of meters. Ehlen (1967) suggested a component of right-lateral strike-slip on the basis of drag features. Despite the complex faulting, it is possible to trace individual sandstone beds and the Lower Member-Middle Member Coaledo Formation contact across the fault zone with a total horizontal separation of about 105 m. Detailed mapping on enlarged aerial photographs taken at low tide also clearly shows that the amount of displacement changes dramatically along the strike of many of the faults.

It is unclear whether the Sunset Bay faults are late Quaternary. Armentrout (1980) observed that the Whiskey Run platform was several meters higher on the south side of the bay than on the north and suggested late Quaternary offset by the Sunset Bay faults. McInelly and Kelsey (1990) also inferred offset of the Whiskey Run platform across the Sunset Bay faults. There is no clear scarp on the projection of the Sunset Bay faults across the Whiskey Run terrace east of the bay, which may be due to the rapid change of displacement along strike observed for other faults in the group. Many of the minor faults on the north side of Sunset Bay are clearly truncated by the Whiskey Run platform.

Miscellaneous faults

A few faults in the area do not clearly fit into the three classes described above. In sec. 12, T. 26 S., R. 14 W., a north-trending, east-side-up fault uplifts the Metcalf platform and tilts it eastward on the upthrown side. A similar fault is inferred in sec. 6, T. 26 S., R. 13 W., on the basis of east-side-up offset of the Metcalf platform. The sense of offset on these faults allows an alternative interpretation of these features as terrace back edges. However, the tilt of the terrace observed in the first example argues for a fault. A similar fault with west-side-up displacement occurs in sec. 2, T. 26 S., R. 14 W. It is indicated by a strong aerial-photo lineament defining the contact between Metcalf terrace sediments and bedrock and by significant tilting of the terrace sediments. Another minor northeast-trending fault occurs in sec. 34, T. 27 S., R. 14 W. It is obvious on historical aerial photographs and clearly offsets the Upper Member Coaledo Formation-Bastendorff contact down to the southeast. There is no evidence for Quaternary movement on this fault.

The last two miscellaneous faults are a pair of northeast-trending east-side-up reverse faults in sec. 31, T. 26 S., R. 13 W., and in sec. 36, T. 26 S., R. 14 W. Both faults are inferred on the basis of photolineations observed on aerial photographs and apparent tilting of marine terrace sediments. It is possible that one or both are terrace back edges.

GEOLOGIC HISTORY

The geologic history of the rocks exposed in the Charleston quadrangle begins in the middle Eocene with deposition of the deep-marine Sacchi Beach beds. The Sacchi Beach beds were subsequently buried by a northward-prograding deltaic complex (Coaledo Formation) fed by rivers draining the Klamath terrane to the southeast (Dott, 1966).

The middle and late Eocene period was punctuated by a series of marine transgressions and regressions. The change from the deep-water Sacchi Beach beds to the shallow-water beds of the Lower Member of the Coaledo Formation indicates the first regression. It was followed by the transgressional period of Middle Member (deep-water) deposition, a second regression marked by the Upper Member (shallow-water), a second transgression marked by the Bastendorff Shale (deep-water), and a final regression during which the shallow-water Tunnel Point Sandstone was deposited. The generally conformable nature of the Coaledo, Bastendorff, and Tunnel Point formations indicates a tectonically stable environment during the time of their deposition.

During the Oligocene and early Miocene, there was a period of nondeposition in the area, probably due to the onset of deformation related to subduction along the Cascadia Subduction Zone. It was during this time that the South Slough syncline began to form.

Not until the late early to middle Miocene did deposition begin again locally in the axis of the syncline with the "Miocene beds" and the Empire Formation. The relatively constant dip through the Coos Head section of the Empire Formation suggests that either the deformation slowed during this period or that the deposition occurred relatively rapidly. The Pliocene was marked by continuing deformation and tightening of the South Slough syncline, without any preservation of Pliocene deposits.

In the Quaternary, two geologic processes were dominant. Continued east-west compression tightened and faulted the South Slough syncline and associated folds, and repeated episodes of marine transgression associated with continental glaciation resulted in the formation and subsequent deformation of several levels of marine terrace. During one of the later periods of marine terrace formation (Whiskey Run or Pioneer?), the Quaternary estuarine sediments were deposited farther inland in valleys drowned by rising sea level.

During the Holocene, alluvial and estuarine deposits filled coastal valleys, and beach and dune deposits migrated inland as sea level rose at the end of the last major glaciation. Although Holocene faulting cannot be conclusively demonstrated in the quadrangle, the number of faults with repeated late Quaternary offsets and preserved scarps suggests that some faulting may have occurred during the Holocene.

RESOURCE GEOLOGY

The Coos Bay area and the Charleston quadrangle have a long history of mineral resource production. Coal mining in the Upper and Lower Members of the Coaledo Formation began in 1854 and continued for about 100 years. Over 3 million tons were produced (Baldwin and others, 1973) from the Coos Bay region. Major mines in the Charleston quadrangle listed by Allen and Baldwin (1944) are the Big Creek Mine (sec. 16, T. 26 S., R. 14 W.; 3,000 to 4,000 tons produced), the South Slough Project (sec. 2, T. 27 S., R. 14 W.; 2,000 tons produced), the Oldlands Mine (sec. 8, T. 26 S., R. 13 W.), and the Vey prospect (sec. 5, T. 26 S., R. 13 W.). Detailed studies of the coal occurrences and workings are available in Allen and Baldwin (1944) and Duncan (1953).

Numerous oil and gas exploration wells have been drilled in or adjacent to the Charleston quadrangle over the years, most recently in 1993 (Steve Pappajohn, Carbon Energy International, personal communication, 1993). Newton and others (1980) summarized oil and gas prospects in the area. No commercial deposits of gas or oil have been found.

Black sand deposits in the marine terrace deposits have been examined for gold, platinum, and chromite. This activity was discussed by Griggs (1945) and Baldwin and others (1973). The major prospects and mines in the Charleston quadrangle described by Baldwin and others (1973) are the Chickamin Mine (secs. 25 and 26, T. 26 S., R. 14 W.) and the Cox Creek prospect (sec. 36, T. 26 S., R. 14 W.).

There are no significant gravel or rock resources in the Charleston quadrangle, largely because the sedimentary rocks present are too weathered or poorly consolidated for use as aggregate, road metal, or riprap.

Groundwater resources are likely to be highly variable in both quantity and quality in the Charleston quadrangle. Although many of the sandstone layers in the Upper and Lower Members of the Coaledo Formation and Tunnel Point Sandstone have moderate to high permeability and would make good aquifers, the strong folding and faulting might limit production. The Empire Formation, Bastendorff Shale, and Middle Member of the Coaledo Formation are largely mudstone and fine dirty sandstone; they probably have relatively poor permeability and are relatively poor aquifers. The marine terrace sands are highly permeable and probably would make good aquifers but are of limited thickness. Water quality in the Coaledo Formation may be affected by the presence of numerous coal beds and carbonaceous sands. All units at low elevation may have water quality problems due to saltwater intrusion.

GEOLOGIC HAZARDS

Geologic hazards and engineering geology of the Charleston quadrangle have been described and mapped by Beaulieu and Hughes (1975). The major geologic hazards in the area are landslides, flooding, tsunamis, and earthquakes. Minor landslides and slumps covering small areas occur on steep slopes underlain by the Middle Member of the Coaledo Formation, Bastendorff Shale, Empire Formation, or marine terrace deposits and were not mapped. There are however no significant large or deep-seated landslides in the quadrangle, despite the fact that many steep slopes are cut parallel to bedding (e.g., east-facing slopes in Big Creek valley). Flooding of low-lying areas is clearly a risk, and care should be taken to site structures well out of flood-prone areas.

Tsunami inundation is a significant risk, particularly for the town of Charleston because of its low elevation and proximity to the bay mouth. Distant tsunamis (originating in Alaska or Japan for instance) will arrive with several hours warning. Local tsunamis (originating from earthquakes just offshore) may arrive within minutes of the causative earthquake. Residents and visitors of the area should consider a strong earthquake to be their only tsunami warning and should seek high ground immediately following an earthquake.

The earthquake risk in the Charleston quadrangle is significant, with over 15 faults showing late Quaternary movement. Local earthquakes of at least M_w 5.5 are possible, based on minimum mapped fault lengths of up to 6 km and empirical relations between fault length and magnitude (Wells and Coppersmith, 1994). In addition, the Charleston quadrangle, like all of coastal Oregon, would experience damaging shaking from subduction earthquakes occurring just offshore along the Cascadia Subduction Zone (Atwater, 1987, 1992; Adams, 1990; Darienzo and Peterson, 1990, 1995; Atwater and Yamaguchi, 1991; Nelson and Personius, 1991; Savage and Lisowski, 1991; Clarke and Carver, 1992). Liquefaction of units Qs and Qal is likely in either local or subduction earthquakes.

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